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Book of Abstracts
November 2-5, 1998

Kellie Ann Beall, Editor

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Distinguishing Normal from Pre-Ignition Conditions to Prevent Cooking Fires on Kitchen Ranges

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A significant portion of residential fires stem from kitchen cooking fires.[1] Previous study has determined that strong indicators of impending ignition for several foods cooked on range surfaces are temperatures, smoke particulates, and hydrocarbon gases.[2] The purpose of this experimental investigation was to determine the physical feasibility of utilizing one or more of these common characteristics of the pre-ignition environment as input to sensors in a pre-fire detection device.

A total of 16 cooking procedures were examined. Simulations of unattended cooking leading to ignition as well as normal, or standard, cooking procedures that have the potential to mimic pre-ignition characteristics were included in the study. Each case was tested on a typical electric range with an inactive range hood. To determine the effects of range type and hood status on sensor performance, two cases were repeated with the range hood active and three cases were repeated on a gas range. The total number of variations was 21, and each test was repeated once for a total of 42 tests.

Both laboratory instrumentation and practical sensors were used to monitor the cooking-area environment. A sample probe carried gases to carbon monoxide, carbon dioxide, and hydrocarbon analyzers. Thermocouples provided temperature measurements near the food and around the range. Hydrocarbon-gas sensors were placed on and around the range. Photoelectric and ionization smoke detectors were placed around the room. Each sensor was evaluated for its ability to alarm before ignition and not generate false alarms.

For results, examples of a few sensors which performed well will be discussed. Figure 1 shows the time traces of 4 sensors located at site 9 which was the center of the front surface of the range hood. The sensors were variations of thin-film tin-oxide sensors tuned to particular families of hydrocarbon gases. The particular test shown was for french fries cooked in soybean oil. The procedure for that cooking case prescribed an initial period of normal cooking followed by an increase to the high heat setting to simulate unattended cooking. In the plot, all of the sensor outputs start to rise around 740 s which was about 30 s after the heat increase. For this particular cooking case and group of range-hood sensors, the levels of voltage produced for the normal and unattended cooking periods show a marked difference which would enable use of an alarm to warn of approaching ignition.

Figure 2 shows a different set of sensors for one test of another cooking case, blackened catfish. These sensors consisted of thermocouples located near the pan. The pan-bottom thermocouple was located between the pan and burner at the center. The drip-pan thermocouple was located beneath the center of the coiled heating element. The food thermocouple was located in/under the food at the center of the inside of the pan. The procedure called for heating butter, placing fish in the pan, turning the fish, and removing the pan from heat. The corresponding times in the plot are 60 s, 240 s, 390 s, and 480 s, respectively. This particular cooking case is a difficult one to accommodate within an alarm system design since the recipe procedure generates temperatures near the ignition point of the butter, and the gases and temperatures produced are similar to those found in unattended cooking cases.

Figures 3 and 4 portray a way to evaluate the magnitude of a window between normal and pre-ignition conditions for sensors at particular locations. Figure 3 shows the voltage output of the cooking-alcohols sensor at site 9 versus test number. The Xs represent maximum output reached during normal cooking periods. The circles represent minimum output experienced during the 30 s preceding ignitions. The dashed line is an alarm threshold chosen to most separate the two output types. Xs above the line represent normal cooking tests that would have caused false alarms with this alarm setting. Circles below the line would represent failures to alarm in situations leading to ignition. For this sensor and location there were 5 tests exhibiting false alarms, and no failures to alarm. Figure 4 is a similar plot to Figure 3, but it is for the pan-bottom temperature. For the chosen alarm threshold, there were 4 tests with false alarms, and no failures to alarm. Better results were found for a simple multiplication of the two signals.

The experimental conclusions are based on measurements of combinations of specific ranges, pans, foods, and ventilation. The major conclusions of this research are: (1) Several sensors offered high levels of differentiation when used alone. Depending on the setting of the threshold, a majority of cooking cases would appropriately cause alarm or not alarm. (2) A limited effort at algebraically combining sets of two sensor signals generated even more robust differentiation. (3) Based on the findings of this investigation, pre-fire detection systems for range-top cooking are physically feasible and merit further consideration of economic viability and practicality.

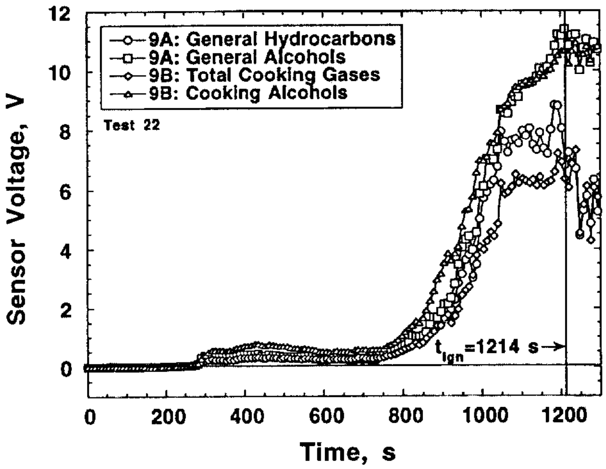

Figure 1. Site 9 Hydrocarbon Sensor Voltages vs Time for French Fries in Soybean Oil

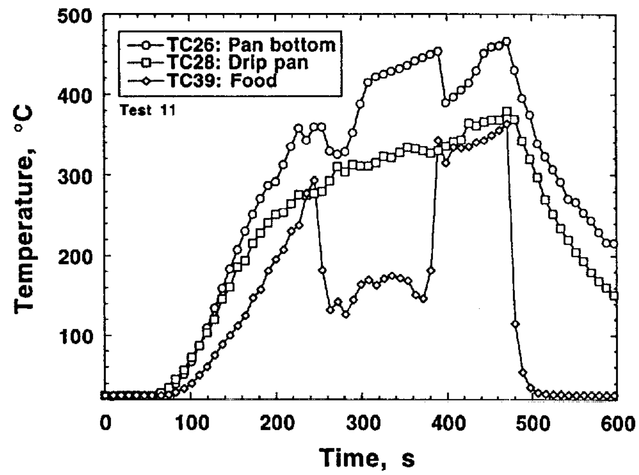

Figure 2: Temperatures vs Time for Blackened Catfish

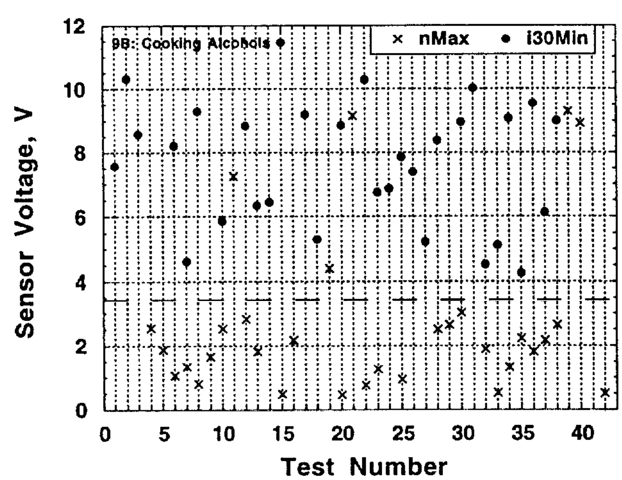

Figure 3. Site 9 Cooking Alcohol Sensor Voltage Max Normal & Min 30 s Ignition vs Test No.

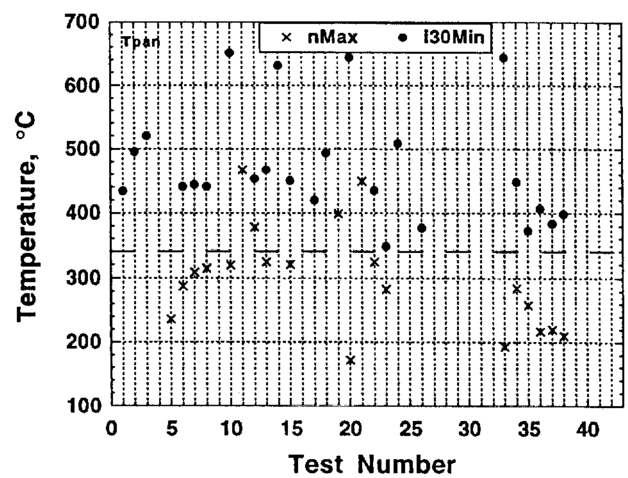

Figure 4: Pan-Bottom Temperature Max Normal & Min 30 s Ignition vs Test No.

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1 Monticone, R., "Range Top and Oven Fires, Statistical Analysis of 1990-1994 Fire Incidents," U.S. Consumer Product Safety Commission, Bethesda, MD; 1997.

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